Development of a Test Chamber with Precise Temperature and Humidity Control for Chemical Permeation Testing

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Objective

- Develop a test chamber with precise temperature and humidity control to reduce variability in chemical permeation testing

Background

- Chemical permeation test methods can be used to evaluate materials for a variety of applications where there is a risk of a chemical hazard.
- Changes in temperature and humidity within the collection flow medium can directly impact material permeation rates. Currently, precision temperature and humidity controls are omitted from existing chemical permeation test methods.
- The ability to effectively control both temperature and humidity should reduce the variability in permeation test methods and allow materials to be evaluated in scenarios more realistic to actual use.
- However, no test systems are commercially available or described in the literature to provide an acceptable level of control.

Experimental Approach

Initial test parameters were based on NFPA 1994 Standard on Protective Ensembles for First Responders to CBRN Terrorism Incidents. The test system design and chamber are shown in Figures 1 and 2.

Humidity

- The target relative humidity level is 80 ± 5%
- Humidifier tube (Fig. 1a) allows for accurate humidity control (Fig. 4)
- Continuous relative humidity monitoring by traceable hygrometer (Fig. 1c)

Temperature

- The target temperature is 32 ± 3ºC
- Collection flow line coils around heat source to increase temperature (Fig. 1b)
- Measuring temperature (Fig. 1c) of collection flow allows for more accurate control (Fig. 5)

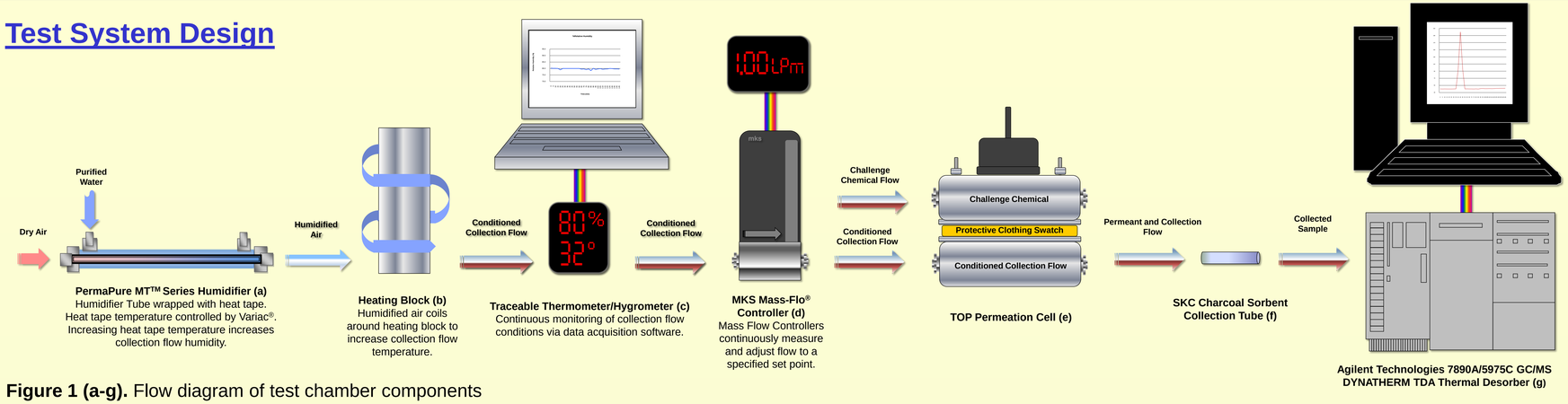
Challenge and Collection Medium Flows

- Mass flow controllers allow for electronic flow monitoring and control independently for each of four cells (Fig. 1d)
- Collection flow maintained at the target flow of 1.0 Lpm
- Mass flow controllers can also be used to control flow for challenge gases

Challenge Chemical

- Acrylonitrile – Example results shown in Fig 3.

Test System Design



PermaPure MT™ Series Humidifier (a) Humidifier Tube wrapped with heat tape. Heat tape temperature controlled by Variac®. Increasing heat tape temperature increases collection flow humidity.

Heating Block (b) Humidified air coils around heating block to increase collection flow temperature.

Traceable Thermometer/Hygrometer (c) Continuous monitoring of collection flow conditions via data acquisition software.

MKS Mass-Flo® Controller (d) Mass Flow Controllers continuously measure and adjust flow to a specified set point.

TOP Permeation Cell (e)

SKC Charcoal Sorbent Collection Tube (f)

Agilent Technologies 7890A/5975C GC/MS DYNATHERM TDA Thermal Desorber (g)

Figure 1 (a-g). Flow diagram of test chamber components

Figure 2. Chemical Permeation Test Chamber with a Single Permeation Cell

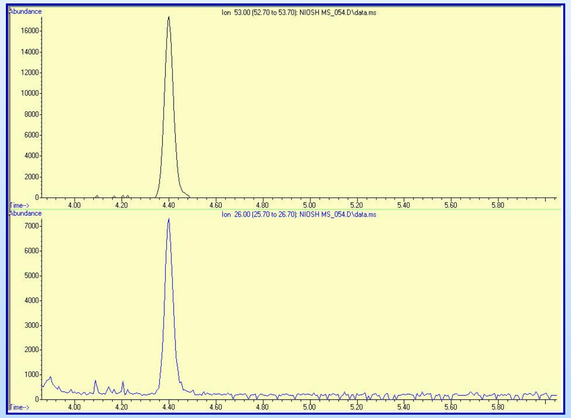


Figure 3. Example acrylonitrile permeation results

Temperature and Humidity Control Results

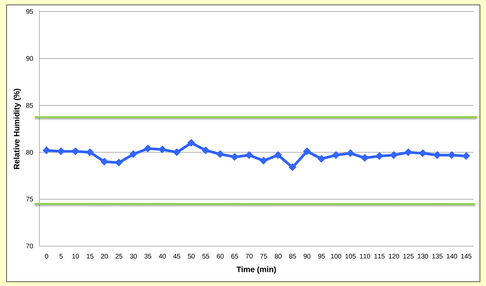


Figure 4. Collection flow relative humidity

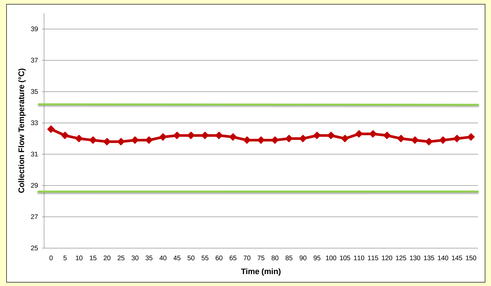


Figure 5. Collection flow temperature

	%RH	Temp. (°C)
Average	79.8	32.1
Max	81.0	32.6
Min	78.4	31.8
Stdev	0.5	0.2
Target	80 ± 5%	32 ± 3 °C

Specification Limits
NFPA 1994, Standard On Protective Ensembles for First Responders to CBRN Terrorism Incidents 2007 Edition

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Conclusion

- Current test system design meets the NFPA requirements for temperature and humidity control for permeation testing

Future Directions

- Now that the test chamber has been established and temperature and humidity control has been validated, future work will focus on additional improvements to permeation testing and further understanding of the impact of various parameters on test results and variability.
- Areas of focus include:
  - Testing of various materials at selected temperatures and humidity levels
  - Adjustment to the TOP cell design for optimal performance and evaluation of other potential cell designs
  - Selection of challenge chemicals and concentration
  - Validation of analytical methodology
  - Determination of appropriate test parameters (relative humidity, temperature, collection gas flow rate, challenge gas flow rate)
  - Automation of humidity controller to further reduce variability
  - Develop new and/or revise existing ASTM standard test methods for chemical permeation using results from the project

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